CLIMATE, OCEAN AND SEA ICE MODELING PROGRAM

The state of affairs in modelling sea ice and its atmosphere/ocean interconnections

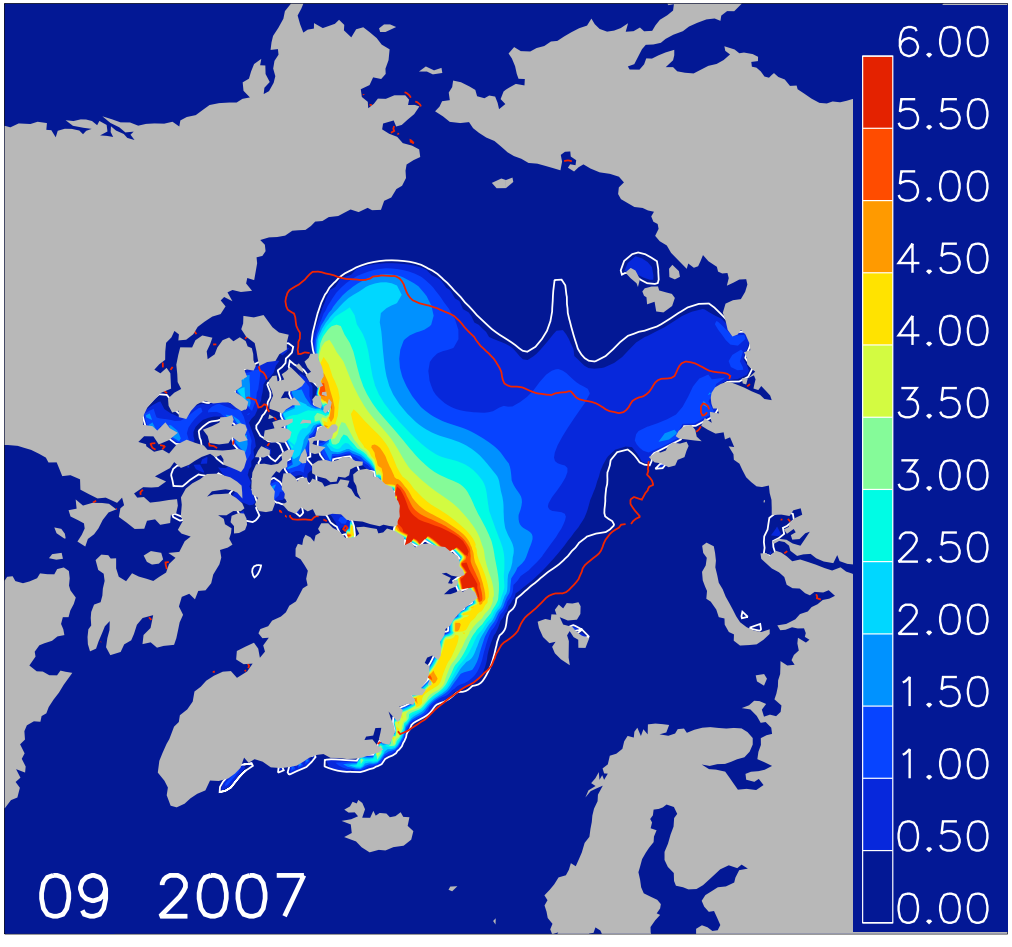
Elizabeth Hunke

June 2013

Monthly Sea Ice Thickness

Ocean Mod. **34**, 2010

SSM/I 15% ice concentration



m

1958–2007 CICE simulation

Interannual variability:

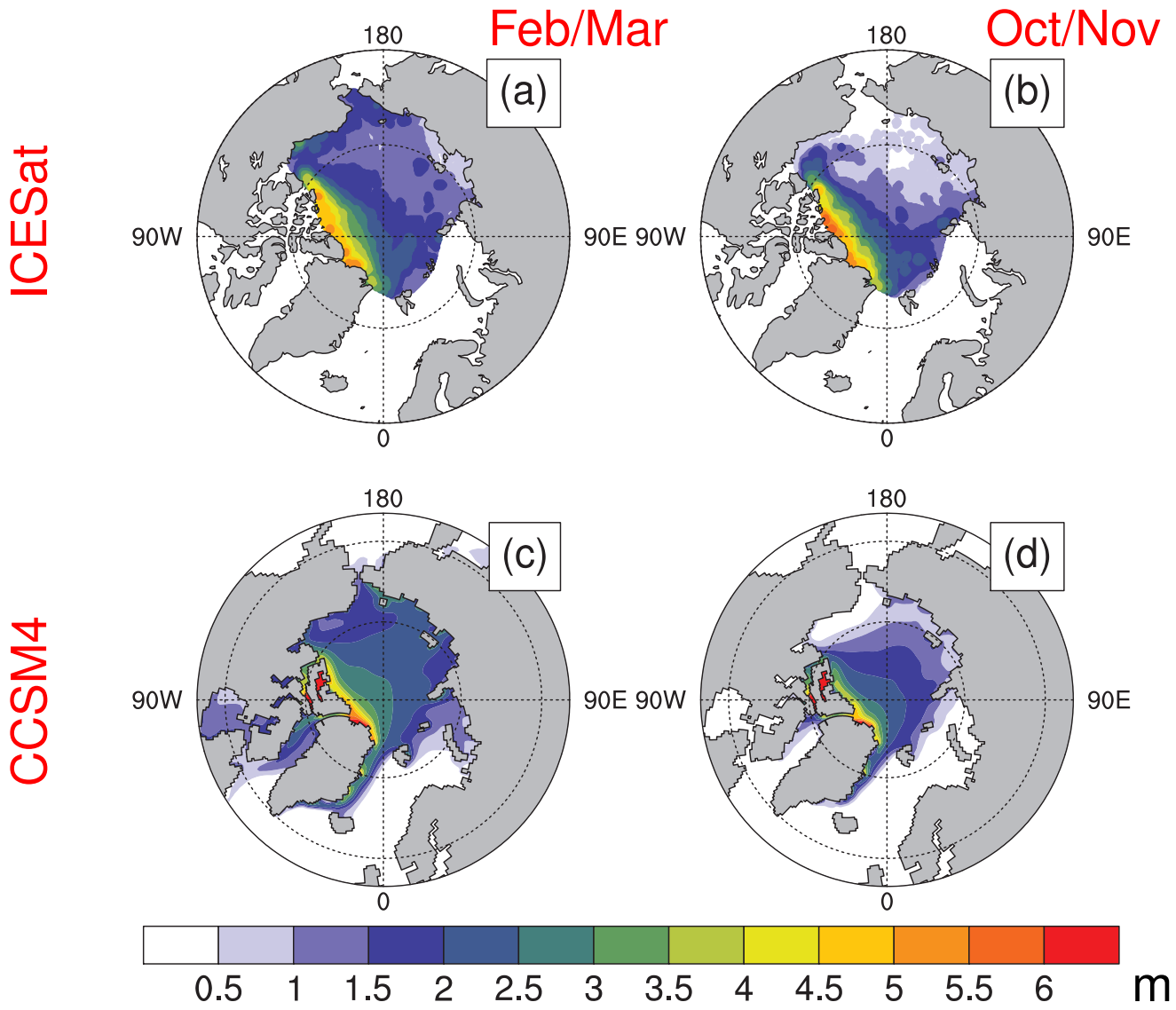
- wind
- air temperature
- humidity

Calculated/ Feedbacks:

- turbulent fluxes
- radiation
- SST
- air temperature

Community Climate System Model 4

NCAR

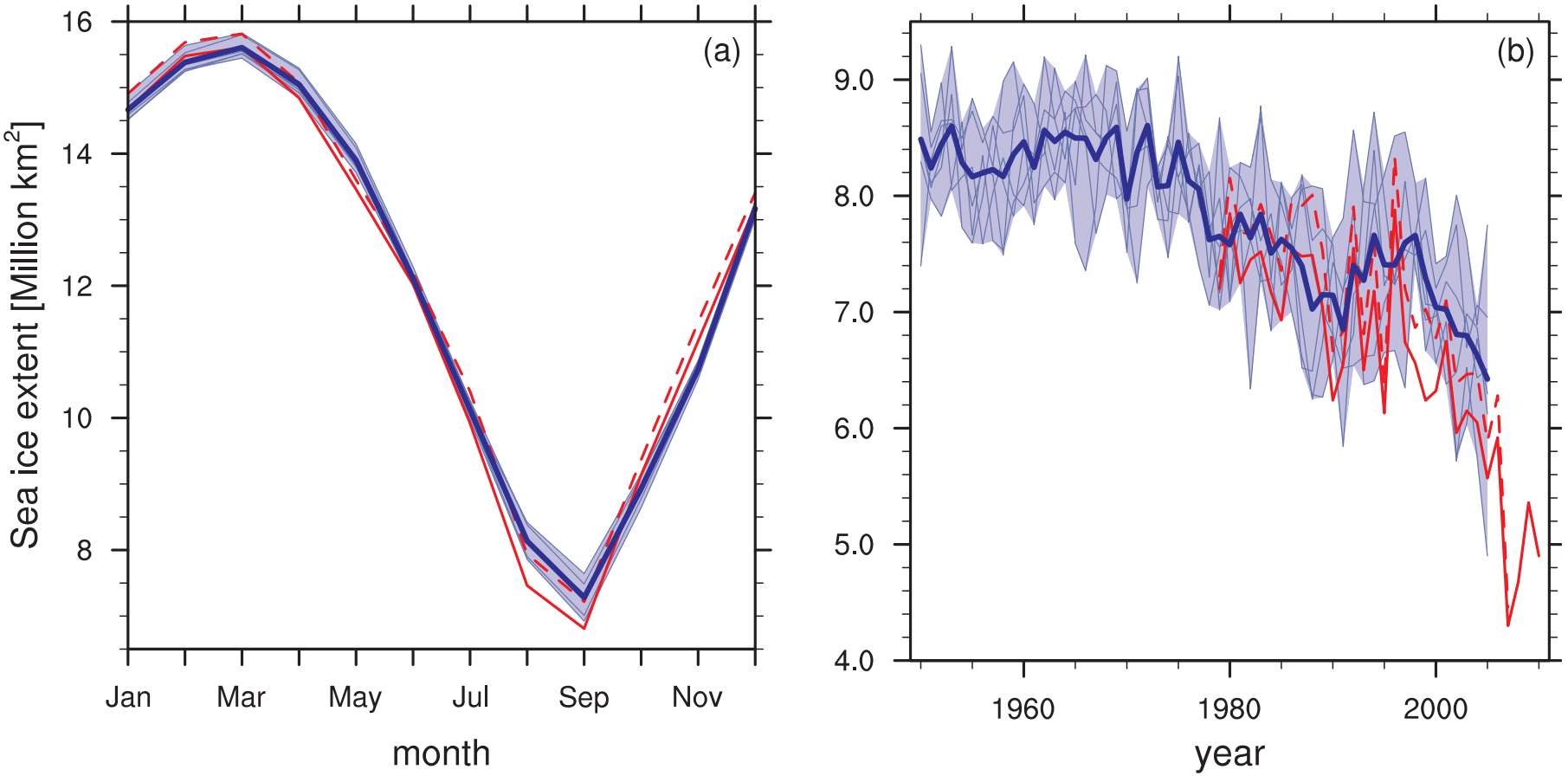


Jahn et al., “Late 20th century simulation of Arctic sea ice and ocean properties in the CCSM4,” J. Clim., 2012

Community Climate System Model 4

NCAR

Arctic sea ice extent



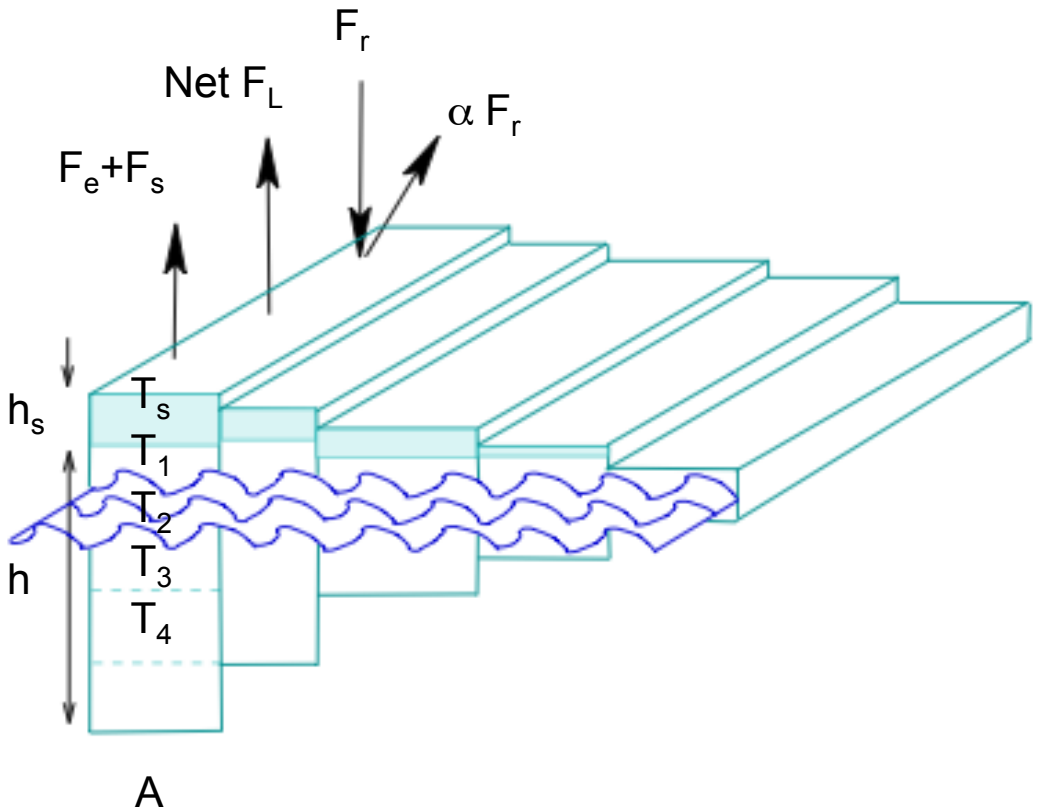
- - - - DMSP Bootstrap

—— DMSP NASA Team

Jahn et al., “Late 20th century simulation of Arctic sea ice and ocean properties in the CCSM4,” J. Clim., 2012

Ice Thickness Distribution *g*

Schematic of model representation of g(H) in five ice "categories"



A=fractional coverage of a category

Slide courtesy Dave Bailey, NCAR

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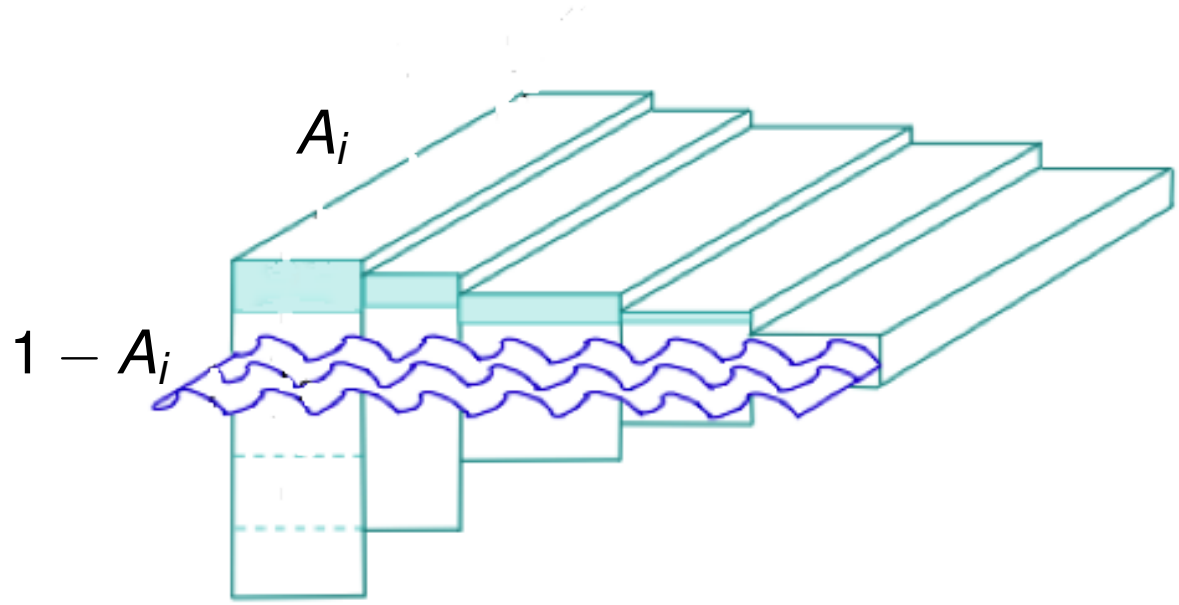

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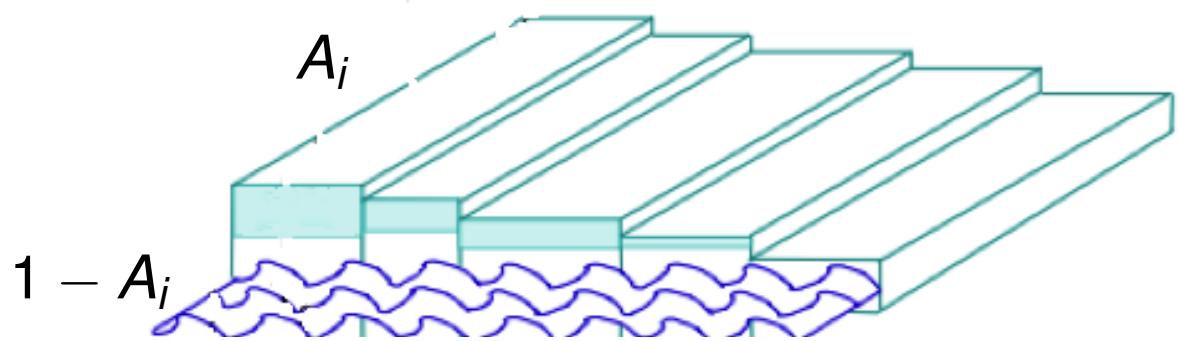

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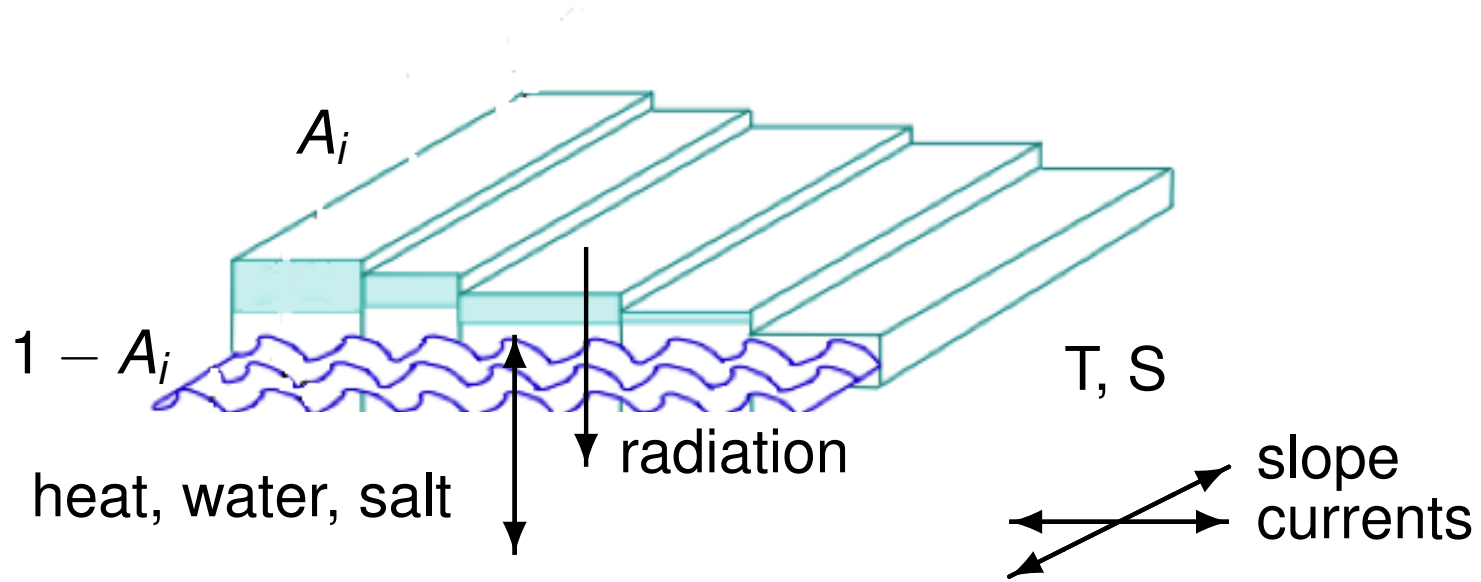
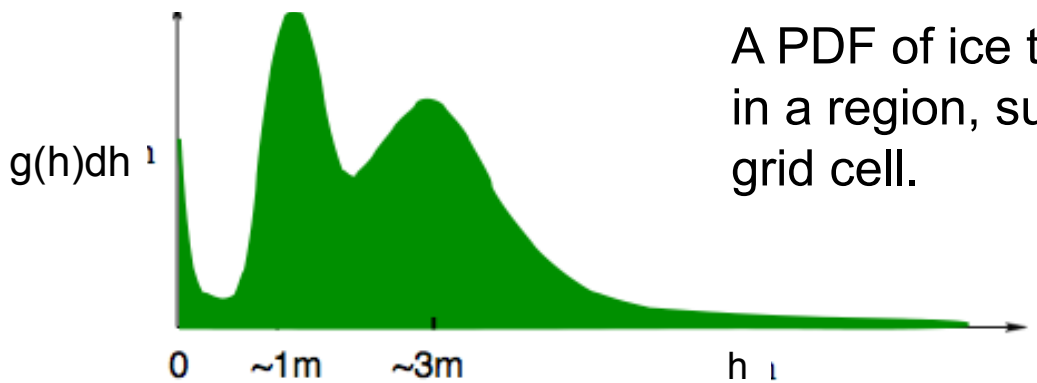


Ice Thickness Distribution g

$g(\mathbf{x}, h, t)\, dh =$ the fractional area covered by ice in the thickness range $(h, h + dh)$ at a given time t and location $\mathbf{x}$

$$\frac{\partial g}{\partial t} = -\nabla \cdot (g\mathbf{u}) + \psi - \frac{\partial}{\partial h}(fg) + L,$$



A PDF of ice thickness h in a region, such as a grid cell.

Ice Thickness Distribution g

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$\nabla = (\frac{\partial}{\partial x}, \frac{\partial}{\partial y})$
$\mathbf{u} =$ horizontal ice velocity
$\psi =$ mechanical redistribution function
$f =$ rate of thermodynamic ice growth
$L =$ lateral melting

What Still Needs to be Done in Sea Ice Models?

Depends on what you want to use the model for

Notz. Challenges in simulating sea ice in Earth System Models. *Wiley Interdisc. Rev.: Climate Change*, **3**, 509–526, 2012.

- radiation melt ponds, zenith angle, soot, extinction coefficient, emissivity
- snow improved thermodynamics, redistribution
- ice-ocean interface stratification effects, friction velocity, false bottoms
- multiphase physics heat capacity, heat partitioning, porosity, bulk salinity, grease ice
- floe size distribution lateral melt, form drag
- dynamics roughness length, rheology, anisotropy, fast ice

Observations needed

Ice at the Interface

Atmosphere-Ice-Ocean Boundary Layer Processes and Their Role in Polar Change

Toward better understanding of boundary processes in the atmosphere-ice-ocean system and their contribution to biogeochemical cycling within the climate system.

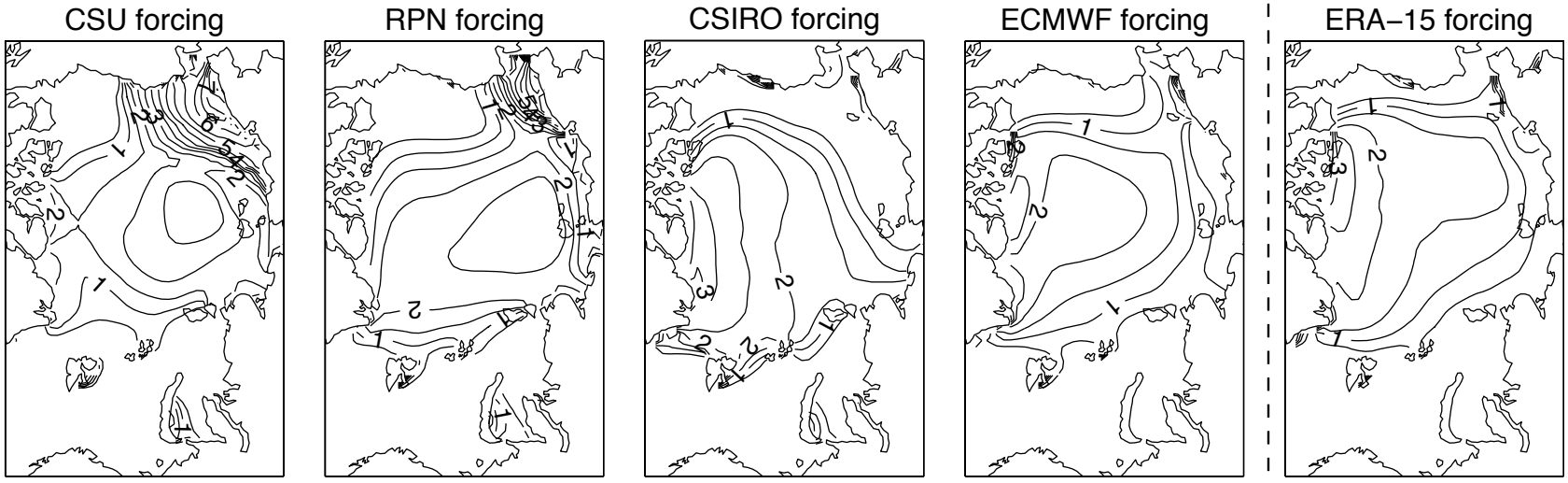
June 25-27, 2012 • Boulder, Colorado USA

Scientific Outcomes

- Theme: Episodic and extreme events
  fracturing, DMS emissions, clouds, freezing fronts in ice
- Theme: Stratification
  mobility, exchanges with deeper ocean, stronger currents
- Theme: Precipitation
  Snow, surface water, clouds/storms, NH/SH differences
- Theme: Marginal ice zone
  wave action, bio/chemical interactions, floe size
- Model development
  priorities: Snow physics, fluid flow within ice, ice-ocean dynamics (especially roughness length), clouds/radiation
  outlook: under-ice ponds, superimposed ice, flooding and snow-ice formation, floe size distribution

Predictability: My (sea-ice-centric) View

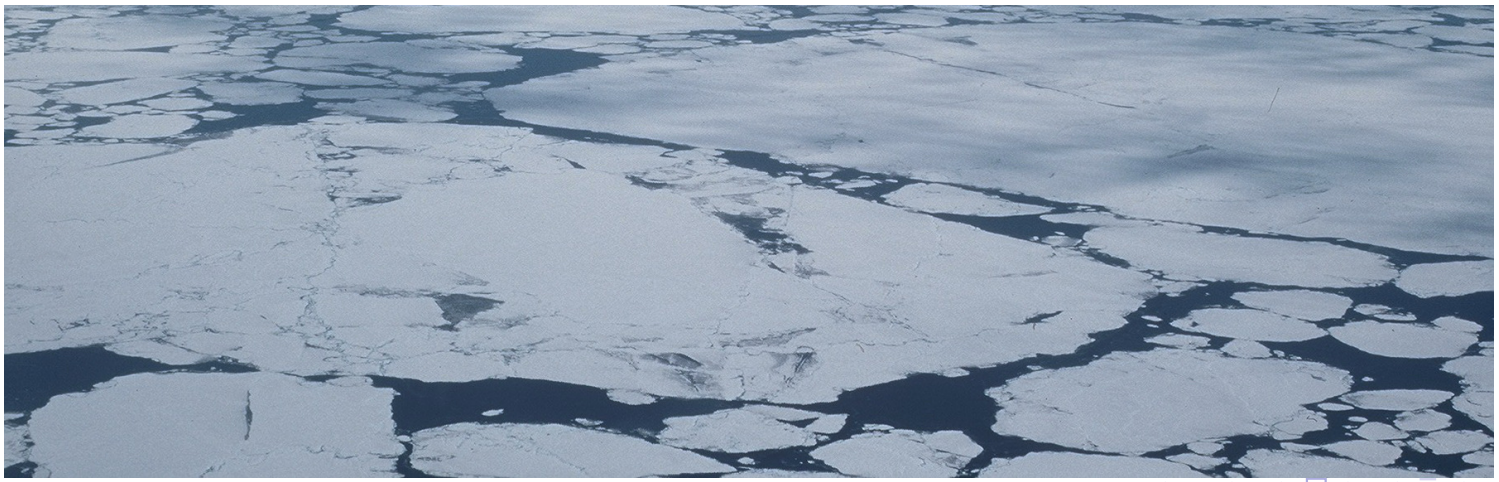
sea ice responds to the forcing applied to it (atm, ocn)



Sep thickness (m)

Bitz, Fyfe, Flato. Sea ice response to wind forcing from AMIP models. J. Clim. 2002.

sea ice amplifies the applied change *in either direction*

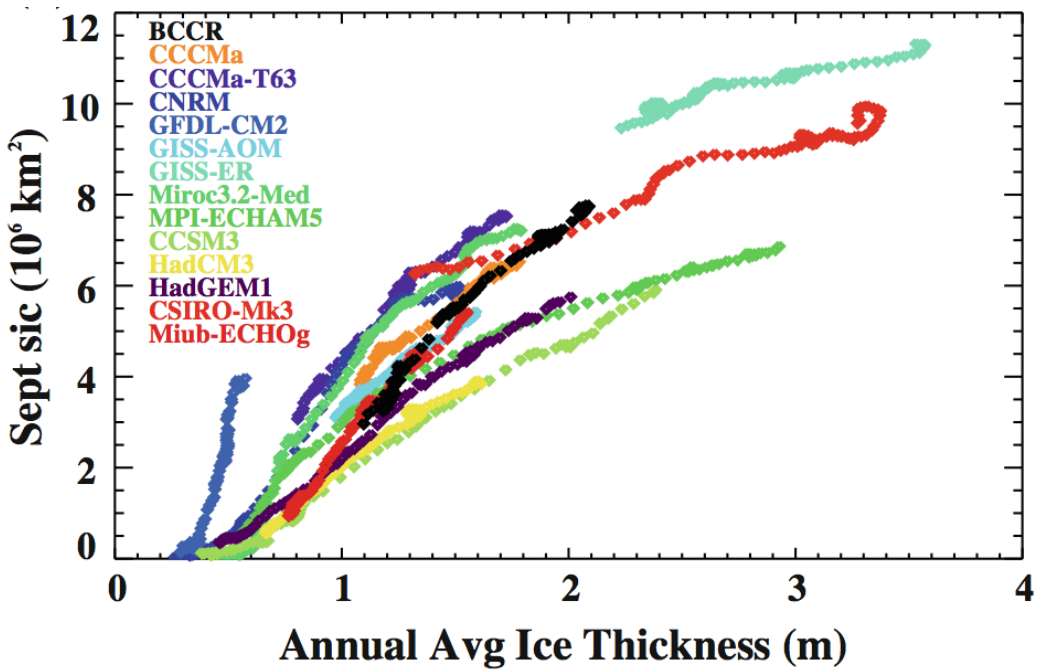


... albedo ...

Predictability: My (sea-ice-centric) View

sea ice predictability is critically dependent on

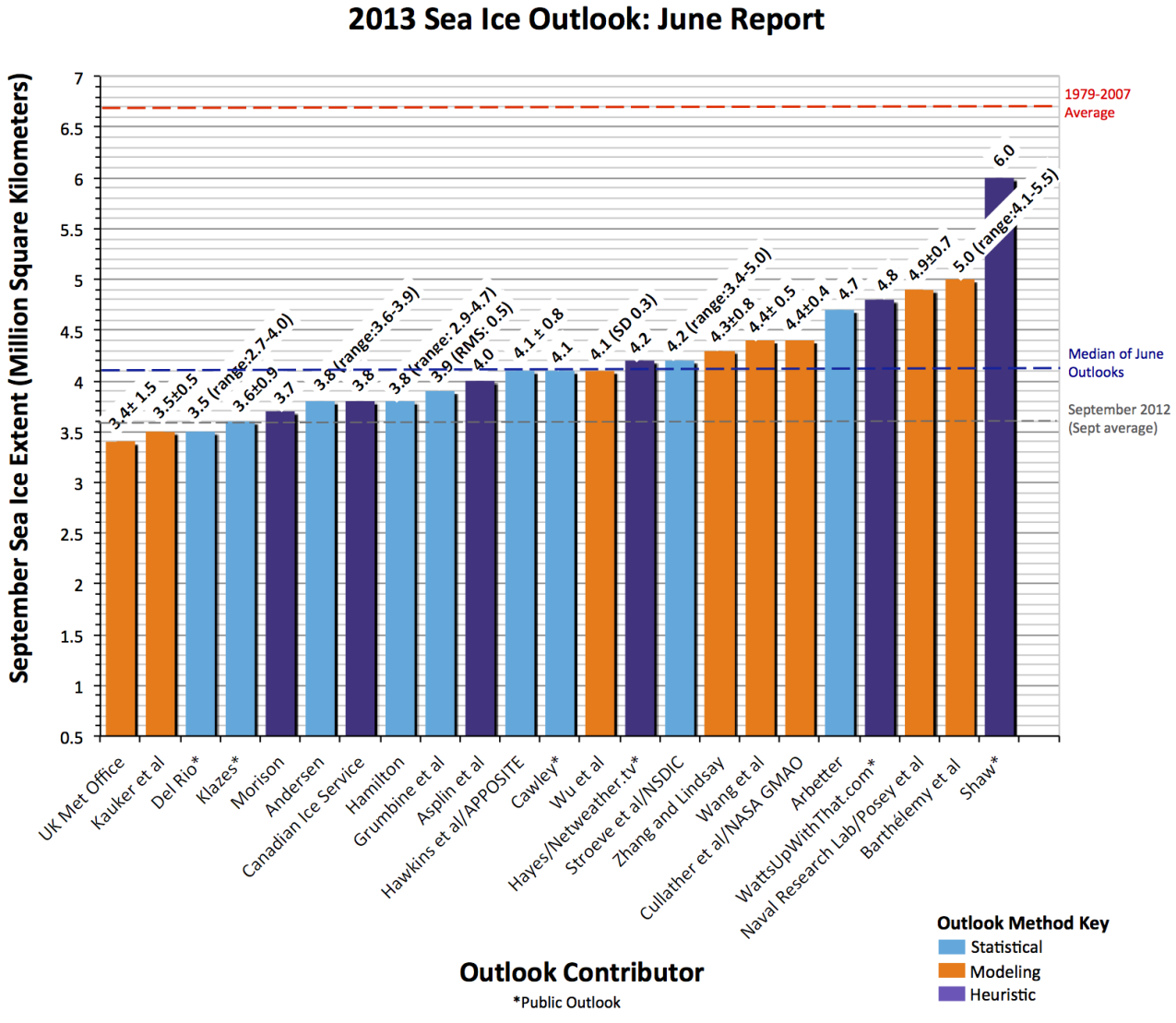
- predictability of the applied forcing
- ice equilibrium state associated with the applied forcing



Holland, Serreze, Stroeve. The sea ice mass budget of the Arctic and its future change as simulated by coupled climate models. Clim. Dyn., 2010.

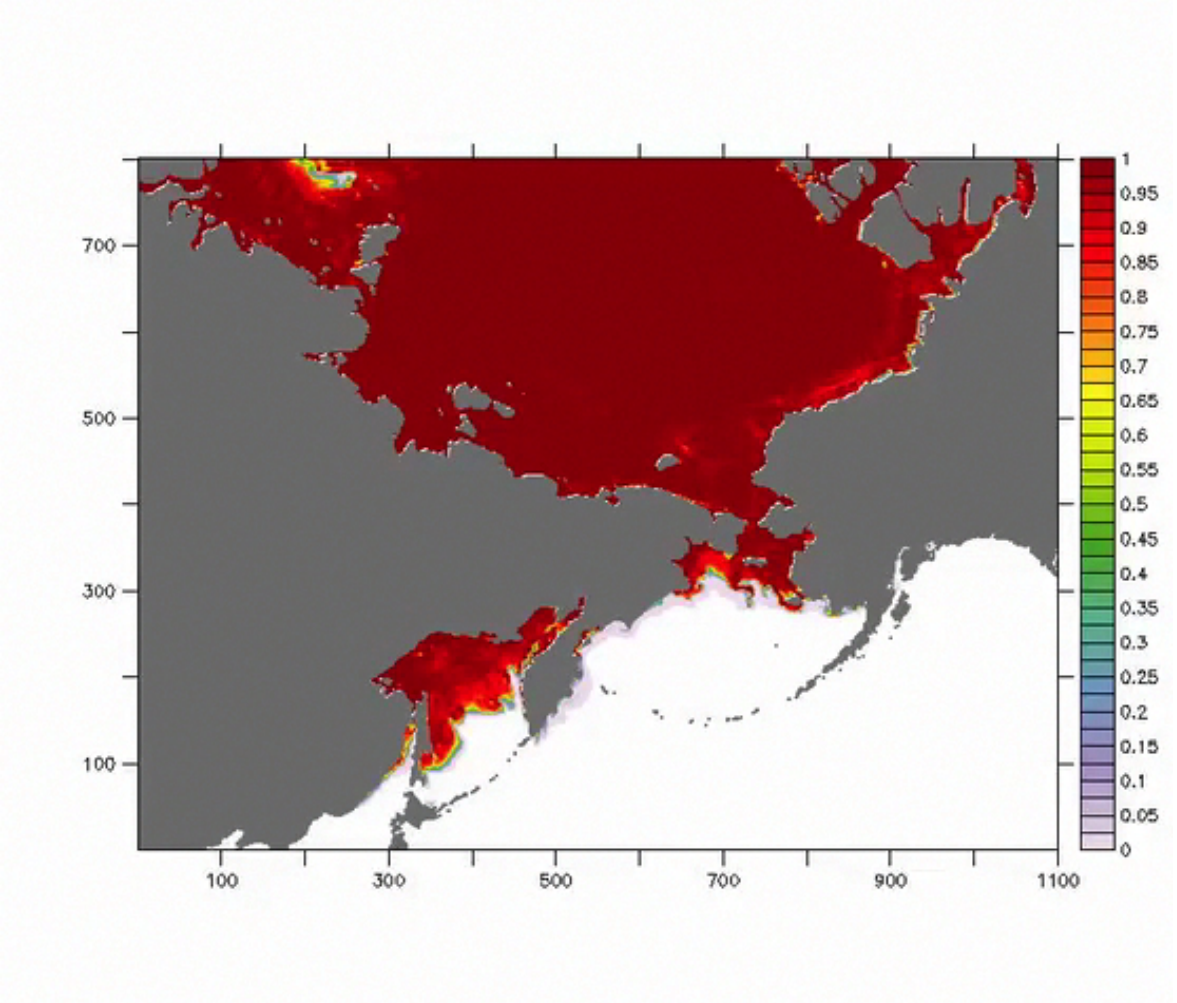
need to focus sea-ice-specific work on
the strength of feedbacks (including atm/ocn fluxes)

June 2013 Sea Ice Outlook



Ice-Ocean Coupling Issues

15-day fully-coupled high-resolution CESM simulation



atm: ne120 cam4

ocn, ice: 0.1°

ice-atm $\Delta t_{cpl} = 15$ min

ice-ocn $\Delta t_{cpl} = 2$ hr

OK for 1, 6 hr

ice $\Delta t_{dyn} = 2.5$ min

ocn $\Delta t = 5$ min

courtesy Mathew Maltrud

Summary

sea ice modeling for climate projection:

First-order processes are well captured

growth, melt, mobility, deformation, albedo ...

for shorter-term prediction, earth system modeling:

Second-order processes are being implemented

ponds, salinity, vertical transport, snow density, anisotropy ...

This Modeler's Perspective on Sea Ice

Fragile

Relatively passive

external forcing balance is critical for simulating base state

strength of feedbacks depends on base state

Much remains to be understood